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## Annular Objective Apertures Improve Resolution of Electron Microscopes

Hollow-cone illumination techniques are used in electron microscopy to increase contrast in images and to improve resolution by minimizing chromatic aberrations. Ordinarily, improved performance is obtained simply by replacing the centered aperture system which provides axial illumination in electron microscopes with an annular condenser aperture, but it has been found that image contrast and resolution can be substantially improved by including an annular objective aperture that is located behind the back focal plane of the objective lens. The size of the annulus is selected so that the cone angle of the diffracted beam at the objective lens is the same as the illumination cone angle provided by the condenser annulus.

The size of the condenser aperture is usually of the order of 2-3 mm in diameter, and the width of the annular open area is about 100  $\mu\text{m}$ . The annular open area is defined by a circle of opaque material centered in a circular aperture; the opaque circle is supported by at least three bars which divide the open area into sections. Condenser apertures of this type can be manufactured mechanically and have already been applied successfully in electron microscopy.

The annular objective aperture, on the other hand, must be about fifty times smaller than the condenser aperture; it is not easily fabricated by ordinary mechanical methods. Moreover, since the improved hollow-cone illumination technique requires maintaining symmetrical cone angles, the size of the annulus in the objective aperture is critical, but it is a simple matter to establish the dimensions empirically. The following procedure for fabricating annular objective apertures provides an annulus of appropriate size for a given electron microscope.

1. A collodion film of about 50 nanometers is stretched

over an aperture holder which can be accurately positioned in the objective aperture slide-carrier of the microscope.

2. A metallic film of a thickness from 20 to 40 nm is evaporated onto the collodion film. The metallic film must be continuous in order to provide a uniformly conducting path for electrons. A thickness of 30 nm has been found adequate for silver films.
3. The microscope is operated in the selected-area diffraction mode. The back focal plane of the objective lens, where the first image of the annular condenser aperture occurs and where the objective aperture diaphragm is supposed to be located, is imaged on the microscope screen.
4. The aperture holder is now set in place in the objective aperture slide-carrier and the assembly is slid into the back focal plane position of the microscope.
5. The image of the condenser aperture is thus made to fall on the metal film; it can still be seen on the screen because both films are somewhat transparent to electrons. Because there are residual gas molecules in the microscope system, a contamination layer is formed on the top of the metal film in the illuminated area, and the image of the condenser aperture will be registered on the metal film. The dimensions and location of the annular aperture which will give optimum performance are thus defined by the contamination layer; the remaining steps of the fabrication procedure transform the contamination layer into openings.
6. The aperture holder is removed from the microscope and slide carrier and put into a copper-plating bath; a thin layer of copper (about 500 nm) will deposit everywhere except on the electrically-insulating contamination layer.

(continued overleaf)

7. Then, the aperture holder is removed to an ion-etching device, and the side with the exposed collodion film is bombarded with argon ions. The ions will first remove the collodion; then, the silver film and the contamination layer will be removed. The bombardment is continued until the aperture is cleanly defined; observations with an optical microscope can be made to ensure that unwanted material has been removed.

8. Finally, the aperture structure is strengthened by evaporation of a thick gold layer (e.g., 2000 nm).

A circular condenser aperture can also be used together with an annular objective aperture to reduce chromatic aberrations. In the central dark-field mode of operation, lattice fringes of 0.118-, 0.144-, and 0.204-nm separation were resolved in microcrystalline particles.

**Note:**

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**Patent status:**

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